REMOTE SENSING CENTRE

RANGELAND MAPPING IN AGRO MANITOBA WITH LANDSAT

L. Horn
G. Lahaie

Manitoba
Natural Resources
Surveys and Mapping

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RANGELAND MAPPING IN

AGRO MANITOBA WITH LANDSAT .

By

Larry Horn
Canada Centre for Remote Sensing

Gil Lahaie
Manitoba Crown Lands Branch

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Centre, Manitoba Crown Lands Branch
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ABSTRACT

Under the terms of the Technology Enhancement Program, the Manitoba Remote Sensing Centre and the Canada Centre for Remote Sensing have conducted a cooperative rangeland mapping project with the Manitoba Agricultural Crown Lands Branch. The purpose of the project was to assess the operational feasibility of using remote sensing techniques for rangeland mapping in agro-Manitoba. The specific objectives were to map recent (i.e. 1981) land cover and to estimate the amount of rangeland affected by flood conditions.

Multidate analysis of 1975 and 1981 Landsat data yielded area statistics for seven major land cover types over an area of 6,650 km^2. Thematic maps at scale 1:125,000 were produced and registered to a topographic base map with a mean standard error of less than one pixel.

Paired comparisons made by cover type for three, 9-section test sites were used to test the null hypothesis that there was no difference in the area of each cover type as determined by air photo and computer classification techniques. The null hypothesis was accepted for each cover type. A comparison of manually generated check training areas with computer classified results for a sample of 9,661 pixels revealed that 9,176 pixels or 95 percent were correctly identified.

Limitations imposed by sensor resolution currently prevent the use of satellite data for making detailed land assessments which are required for administration of leases and permits of occupation. The project has demonstrated that satellite data can be used to map land cover types for the Agricultural Crown Lands Branch at a level of detail that is sufficient for regional planning.

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1. INTRODUCTION

1.1 Background

The Manitoba Remote Sensing Centre (MRSC) in cooperation with the Manitoba Department of Agriculture, Crown Lands Branch and the Canada Centre for Remote Sensing (CCRS) conducted a rangeland mapping project in northern agro-Manitoba. The study was one in a series of eight demonstration projects conducted under a joint Federal/Provincial Technology Enhancement Program (TEP). The objective of TEP was to enhance the scientific and technical capabilities of remote sensing technology to resource management activities.

The purpose of this report is to document the mapping techniques used and the results of the project. In addition, the potential for incorporating remote sensing techniques into existing operational programs of the Crown Lands Branch is examined.

The Management and administration of Crown Land in Manitoba is divided between two departments, the Departments of Natural Resources and Agriculture. The Agricultural Crown Lands Branch is responsible for issuing agricultural leases and permits of occupation or use of Crown Lands designated by the Minister of Natural Resources as:

1) primarily agricultural lands, and
2) multiple use lands which may only be used for agricultural purposes on an interim or secondary basis.

The agricultural use of suitable Crown Lands are administered through a lease and permit system. Annual rentals are calculated on the basis of resource productivity which is measured by the Forage Production Capacity (carrying capacity). The unit of measure is the animal-unit month (AUM) which is defined as the amount of forage required by an animal unit for one month of grazing (Heady 1975). An animal unit is defined as a 455 kg cow with an average daily consumption of 12 kg of dry forage matter. An AUM can be described as a specific volume of dry matter forage and is estimated on the basis of forage production from leased land.

1.2 Resource Issue

Rangeland types differ in their capability to produce forage depending on species composition, climatic conditions, soil type and drainage. From a land use perspective, over one-half of the soils in the study area are either imperfectly to poorly drained or are under the periodic hazard of flooding or swamping. In general, limitations of the soil and certain physical features have inhibited or favoured only partial conversion of the area to productive farmland. To take advantage of those production areas, farmers and ranchers obtain various kinds of grazing or hay leases that enable them to utilize natural grass and scrub land under control of the Crown or of the Local Government District. An overall perspective of land use in the study area would assist rangeland managers in developing regional management schemes.

1.3 Objectives

The purpose of this study was to determine the operational feasibility of using remote sensing techniques for mapping range land. The specific objectives of the study were to:

1. map land cover in the study area for 1981,
2. show that satellite data could be used to estimate the amount of rangeland affected by flood conditions.

Of equal importance to the specific objectives, was the active participation of staff at the Crown Lands Branch in this project. Their involvement during each phase would provide them with a first-hand opportunity to learn about recent developments in remote sensing.

1.4 Study Area

The study area was located approximately 250 kilometres northwest of Winnipeg on the northern fringe of agro-Manitoba (Figure 1). Lying just to the east of the Manitoba Escarpment, between Dauphin Lake and Lake Manitoba, the area of interest covered approximately 6,650 km^2. The main physical and landscape features of the region have been influenced by the nature of the rock formations, the superficial deposits derived therefrom and the dynamic forces of glaciation and glacial lake action (Ellis 1964).

Calcareous (high-lime) rock formations with a relatively shallow overburden of till or mantle of varying depth form the dominant parent material. Other materials carried westward into the area by glacial ice as well as surface deposits carried eastward by erosion from the Manitoba Escarpment have resulted in a matrix of glacial drift characterized by a wide assortment of stones, boulders, cobbles and rock fragments.

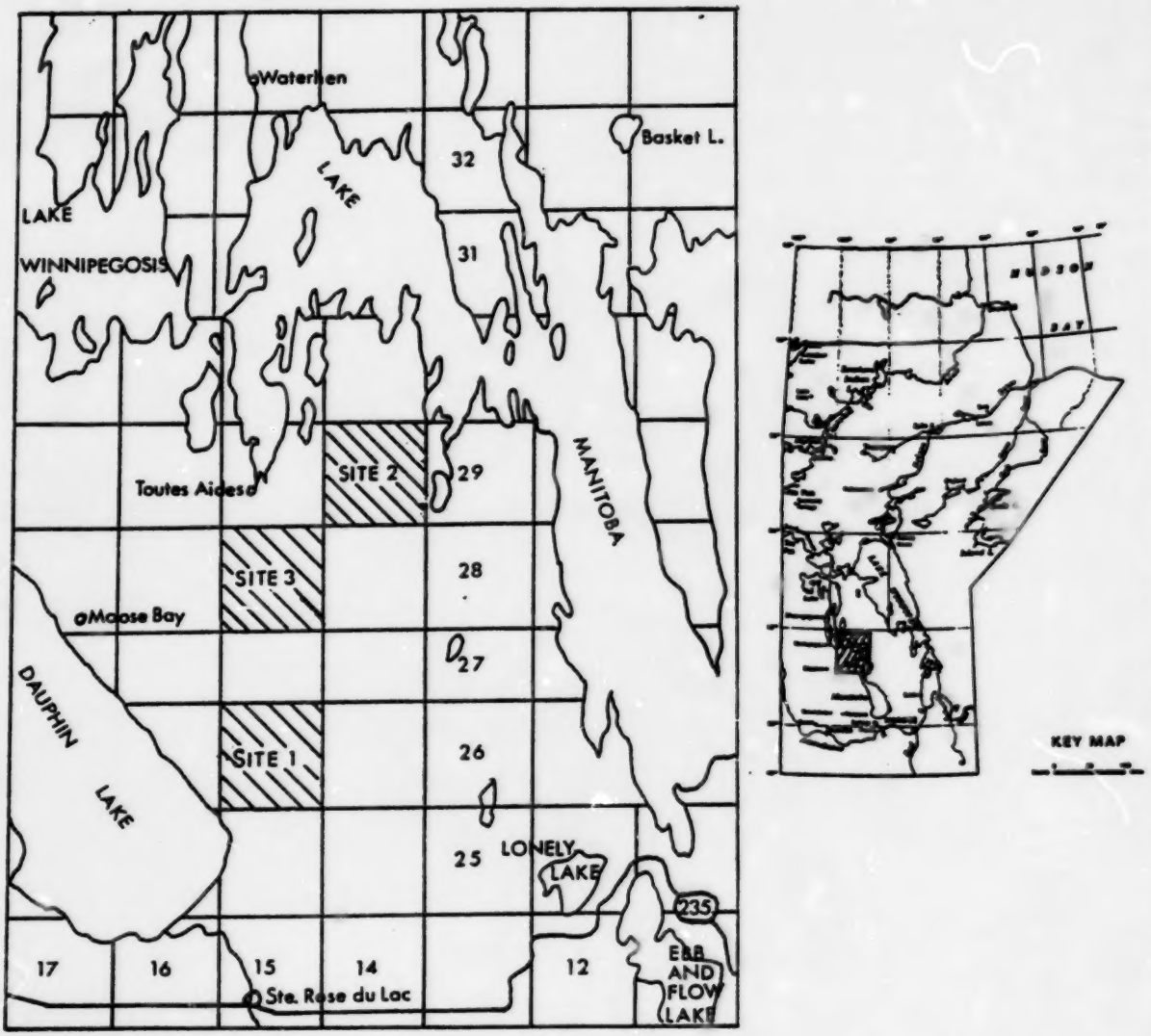

Figure 1. Study area and test site location for the Rangeland Mapping project.

The development of surficial materials has been profoundly influenced by the lay and slope of the land. Generally, the slope moves gradually eastward from the foot of the Escarpment to the Lake Manitoba - Lake Winnipegosis basin and levels out in many places to form flat or depressional sites. The overall effect has been the development of thin or shallow soil profiles with relatively poor surface drainage. Add to this the problem of fluctuating ground waters, high in electrolytes, and the result is a large land area which requires intensive soil management before it can be put to good agricultural use.

The study area may be considered vegetatively as a transition zone between the mixed boreal forest of the Manitoba Lowlands and the Aspen-Oak Parkland. North and east of Lake Manitoba the prevailing vegetation consists of trembling aspen (Populus tremuloides) and balsam poplar (Populus balsamifer) with black spruce (Picea mariana) and tamarack (Larix laricina) in the swamps. East of Dauphin Lake lies the Aspen-Oak Parkland characterized by aspen, balsam poplar and to a lesser extent bur oak (Quercus macrocarpa). Where conditions are favourable, the forest is more or less closed whereas on other sites it occurs as groves mixed with meadow-grassland and open swales.

Many of the open grasslands in this area today are remnants of more extensive grasslands from the past. The periodic history of wildfires and the high soil salinity which inhibits tree growth were two important factors contributing to the existance of large grasslands. As agricultural development moved north, many of the natural grasslands were put under the plough, wildfires became less prevalent and drainage schemes were developed. Today the remaining prairie grasslands include Tall Grass, Fescue and Mixed Prairie vegetation types.

1.5 Cover Type Classification

The Crown Lands Branch recognizes several broad vegetation types in their system of land clsssification. These categories range from woodland pasture through lowland and upland meadows with each containing a variety of forage sources. All forage sources differ from one another in productivity and quality depending on site conditions; however, general productivity values can be assigned to these broad vegetation types.

The cover type classification system developed for this project is a modification of the Crown Land System (Table 1). Level II categories in the Crown Land System are used to establish general rangeland productivity. However, at the administrative level (i.e., assessment of rental fees) variations in species composition and production must be considered.

Given the dates of imagery that were available, slight modifications at level II were required for interpretation purposes. Although information derived from satellite data was presented at level I the detailed description of level I categories is given at level II. The following is a description of mapping units used for this project:

I WOODLAND - This category includes all land dominated by deciduous and coniferous tree cover. Occasional openings in tree cover on poorly drained sites may support sedges (Carex spp.) and marsh reed grass (Calamagrostis canadensis).

Table 1. Comparison between the Agricultural Crown Land Classification System and the Landsat Based Classification System

Agricultural Crown Land System		Landsat Based Classification System	
LEVEL I Description	LEVEL II Description	LEVEL I Description	LEVEL II Description
I WOODLAND	a) True Forest b) Dense Deciduous Woodland c) Open Deciduous Woodland d) Sprayed Deciduous Woodland	I WOODLAND	a) Open to Closed Woodland b) Sprayed Deciduous Woodland
II GRASSLAND	a) Unmodified Rangeland b) Modified Natural Uplands c) Midland Natural Vegetation	II UPLAND MEADOW	a) Unmodified Rangeland b) Modified Natural Uplands c) Abandoned Cropland
III WETLAND	a) Sedge Meadows b) Marshes	III LOWLAND MEADOW	a) Midland Natural Vegetation b) Sedge Meadows c) Abandoned Cropland
IV CULTIVATED	a) Arable Cropland b) Tame Forage c) Abandoned Cropland	IV WETLAND	a) Marshes
		V AGRICULTURE	a) Arable Cropland b) Tame Forage
V UNSUITABLE AGRICULTURAL AREA	a) Rock, Saline, Gravel Pits	VI UNPRODUCTIVE	a) Rock, Saline, Roads
		VII WATER	a) Lakes, Rivers, Ponds

Openings in well drained areas are usually dominated by hairy wild rye (Elymus innovatus), brome grass (Bromus spp.), Vetches (Vicia spp.) and pea vines (Lathyrus Venosus).

II UPLAND MEADOW - The upland meadow category is a composite of level II classes from the Crown Land System. This cover type contains unmodified rangeland and modified natural upland vegetation from the GRASSLAND category as well as abandoned cropland in various stages of natural revegetation from the CULTIVATED category.

Only scattered remnants of unmodified rangeland remains. Common grasses on these sites include big and little bluestem (Andropogon spp.), switchgrass (Panicum virgatum), prairie cordgrass (Spartina pectinata), rough fescue (Festuca spp.), June grass (Koeleria cristata), bluegrasses (Poa spp.) and alkali cordgrass (Spartina gracilis).

Large areas dominated by upland grasses which have been disturbed at one time by cultivation are typically referred to as native pastures. In some area allowed to regenerate naturally to grass. Species composition is variable depending on site; however, bromegrass, wheat grasses (Agropyron spp.), fescues and timothy phloem pratense) are most abundant.

Abandoned areas on well drained sites that were at one time cropped or grazed have been included in this category. This is a difficult cover type to identify because the term abandoned relates more to land use than land cover. It is worthwhile noting that it is the reflectance of the land cover and not the land use per se that is detected by the satellite sensor.

III LOWLAND MEADOW - This category is also a composite of level II classes in the Crown Land system. The cover type contains the ecotonal "midland" natural vegetation from the grassland category, sedge dominated meadows from the wetland category and abandoned cropland from the cultivated areas.

Midland vegetation is the transitional area between uplands and wetlands. Species composition is usually a mixture of plants from both communities varying in occurrence with moisture conditions. Shrubby vegetation such as snowberry (Symphoricarpos sp.) and silver berry (Elalagnus commutata) are common as well as isolated aspen clumps. Sedge dominated meadows are found in poorly drained areas and are subject to periodic spring or summer flooding. These areas are dominated by lowland sedges, reedgrasses and in some areas rushes (Juncus, spp.). Forage production from these areas are high, but palatability for cattle is lower than in upland areas.

This category also include abandoned cropland on poorly drained sites.

IV WETLAND - Included in this cover type is true marsh vegetation which is generally considered to be too wet for continuous agricultural use. Standing water on a year round basis is a common occurrence. Vegetation is dominated by marsh reeds cattails (Typha latifolia), rushes and sedges.

V AGRICULTURE - This cover type contains all cultivated areas such as tame forage and cropland. Bush or meadow which has been converted to tame forage will have variable productivity according to soil capability and management. Croplands are areas utilized for annual arable culture. Distinction of field crops was not made.

VI UNPRODUCTIVE - These areas support very little vegetative growth and includes, roads, sand and bedrock and widely scattered occurrences of surface soil salinity.

VII WATER - This category includes all lakes, rivers and ponds of open water.

2. METHODS

2.1 Data Acquisition

Aerial photographs of the study area were examined to determine the extent of their coverage, scale, type and dates. Complete coverage of the area was available from photographs at a scale 1:15,840 black and white format for the years 1974 and 1980.

Landsat microfiche were examined to determine the availability of satellite data for the area. Selection criteria included a cloud free image some time in the period between early July and late August. Optimum satellite data would correspond with the 1974 and 1980 aerial photography. The following Computer Compatible Tapes (CCT) from track 35, frame 24 were selected for analysis:

Image Date	Cloud Cover
June 16, 1974	5%
September 9, 1975	0%
May 19, 1981	0%

The June 1974 image was representative of a year with "wet" growing conditions; however, a large area of haze over the study area rendered most of the image unsatisfactory for supervised classification. The remaining two images were representative of a year with "dry" growing conditions; however, both image dates fell outside the optimum time period. Although the data available was by no means optimum, the decision was made to go ahead with the project and derive as much information as possible.

2.2 Test Site Selection

Three test sites containing representative cover types within the study area were selected for detailed analysis (Figure 1). Test site number one was located in township 26, range 15 and was most representative of meadow and agricultural land. Test site number two in township 29 range 14 was representative of forested and wetland areas. Test site number three was located in township 28 range 15 and represented meadows and wetlands.

Land cover types within a nine section contiguous block were delineated by air photo interpretation methods. The area of each cover type was measured with a planimeter and compared with area measurements taken from computer classified results. The air photo interpretation served as ground reference data for conducting the supervised classification.

2.3 Image Analysis

Computer analysis of satellite data was performed with the Applied Resource Information Exploitation System (ARIES-II) image analysis system using Version 2.1 of the AII ASP software. Image analysis operations were conducted in three phases with the general sequence of operations shown in Figure 2. Phase one consisted of image preprocessing including geometric corrections and image to image registration. Phase two processing resulted in production of a classified image. The third phase consisted of post classification filtering, manual theme assignments, area calculations, accuracy assessments and generation of output products.

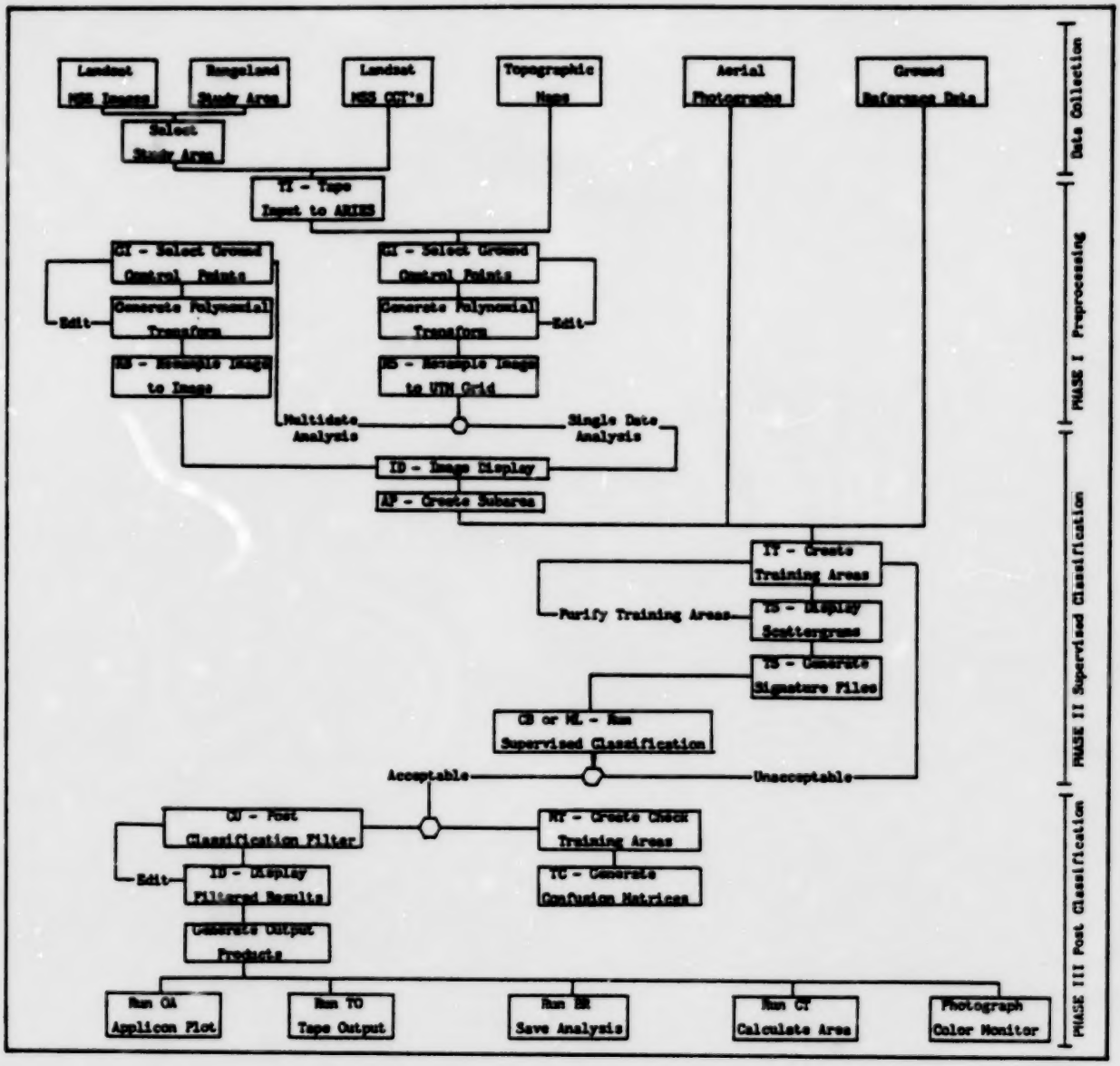

Figure 2. Flow chart of image analysis procedures followed on the ARIES - II image analysis system. Programs indicated by the two character identifiers are for version 2.1 of the AII ASP software package.

2.3.1 Image Preprocessing

Image preprocessing operations consisted of image to Universal Traverse Mercator (UTM) grid registration and image to image registration. The first step in the image to grid registration was to generate a series of ground control points (GCP). GCP's are well-defined points that can be identified by their coordinates on the satellite image as well as on the UTM grid system. Six GCP's identified by their line/pixel coordinates on the satellite image were linked to northing/easting coordinates on the UTM grid system. The image transformation or change in image geometry was accomplished by a second order affine transformation (Shlien 1979).

Automatic image loading by the ARIES-II system as well operator defined image loading techniques were used in the geometric correction process. The advantage of automatic loading is that annotation of each GCP is placed on the image and the system automatically calculates the appropriate GCP power using a polynomial transformation. The major disadvantage of this method is that only one MSS band can be loaded automatically making it difficult to locate some GCP's. With operator defined image loading, as many as three MSS bands may be displayed simultaneously. Information from two or more bands may be combined to assist the analyst in visually locating the exact position of the GCP. The automatic image loading option is perhaps a little quicker but only in areas where GCP's may be easily located using information from only one MSS band.

Similar principals of linkage and image transformation are followed when conducting image to image registration. Common points on both images are identified and again a polynomial transform is used to change one image's geometry to conform with that of another image. Eleven GCP's were selected for image-to-image registration.

The second step in the image-to-grid or image-to-image registration process is to generate a new feature file by resampling an input feature file according to the parameters in the polynomial transform file. Transformation coefficients calculated by linear transformation functions were used as input into the resampling algorithm. The cubic convolution algorithm was used to resample each feature file (raw MSS data). In resampling from image to grid the standard 79 m x 59 m pixels were resampled to 50 m x 50 m pixel size.

There are two important aspects to consider when performing preprocessing operations. Each output image from the image-to-grid registration must have the same minimum and maximum UTM limits if they are to be registered to one another. Also, for each GCP the specified northing and easting coordinates must fall between the minimum and maximum limits which delineate the area to be corrected. Another point to consider is that the three character area name for the output "slave" image must be the same as the "master" image when performing image-to-image registration. Failure to implement these steps will likely result in aborted batch jobs during batch processing.

2.3.2 Image Classification

The objective of this phase was to produce a classified image. It was during this phase that ground reference data played a critical role.

Ground reference data was used to "train" the computer to recognize cover types of interest. Reference data may be in the form of air photo interpretation, ground truthing or some other form of site verification. It was imperative that ground reference data show not only areas with known ground cover but also their exact geographic location.

Training refers to the process of defining areas on the satellite image that contain pixels representative of only one vegetation cover type. Every pixel within a training area relays significant spectral information about that cover type to the computer. It is therefore important to be selective and exact when choosing and defining training areas. Several training areas for the same cover type were selected from different locations on the image. In doing so, slight differences in spectral reflectance due to site-specific conditions were accounted for in the training set. A training set is comprised of all training areas created for the same cover type.

When selecting training areas it is advisable to avoid "border" pixels and to select large training areas that contain at least 3/4 of the desired ground cover type. Border pixels may possess a spectral signature that differs from the "true" signature because of the influence that neighbouring cover types have on the total reflectance. The same reasoning applies when selecting a training with at least 3/4 of the desired cover type. A training area purification process can be used to eliminate unwanted or nonconforming pixels from a training set.

Nonconforming pixels can be detected by observing a scattergram of band 5 versus band 7 for each training set (Figure 3). The scattergram, generated under program TS, is a standard X-Y plot representing two-dimensional vector space. The distance from the origin in the X direction is determined by reflectance values in band 7 and in the Y direction, by reflectance values in band 5. For each training set, the scattergram pattern and location in vector space is important for understanding where confusion might be expected to occur in the classified results. Confusion can be expected whenever two spectral clusters meet or overlap. By reducing the amount of overlap, confusion between cover types was reduced at the expense of having more of the image left unclassified. Non-conforming pixels in the training set were removed by a purification process.

Training area purification is a process whereby a maximum likelihood thresholding function is applied to all pixels in a training set. Only those pixels which fell within an operator-defined percentage of the mean were retained. After each purification run, the scattergram with the reduced data set was viewed. If necessary, the purification process was conducted several times until overlap with adjacent training sets was minimized. A spectral signature made from spectral values in all four MSS bands is calculated for each training set and is later used as input into the maximum likelihood classifier.

The fast maximum likelihood classifier running under program CB classifies a four feature data set and separates up to 16 classes. Basically, the computer examines spectral values of each pixel and classifies each pixel according to the spectral signature generated from the training set.

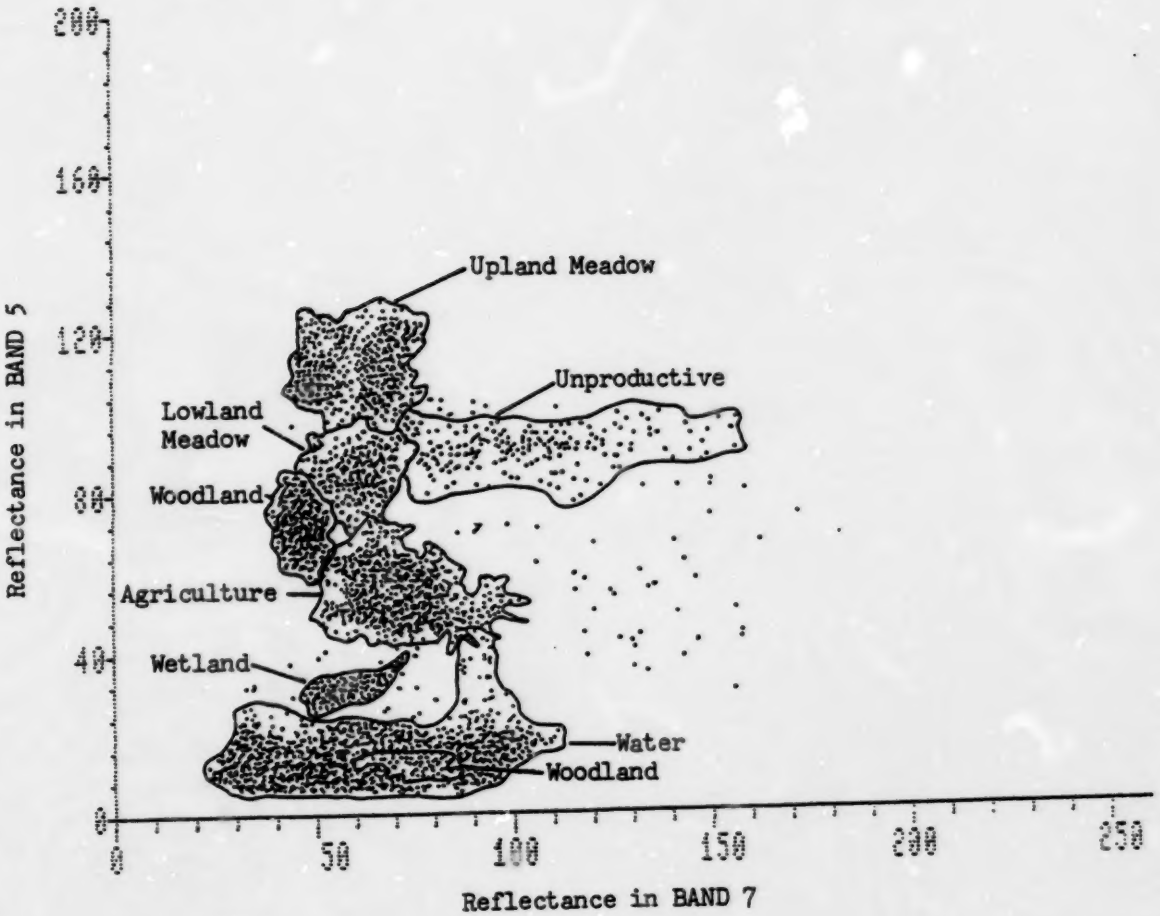

Figure 3. A scattergram showing reflectance values of band 7 versus band 5 for each land cover category.

2.3.3 Post Classification Analysis

Often when a classified image is viewed for the first time a preliminary assessment by visual methods is sufficient to decide whether to proceed with detailed post classification work. To conduct this preliminary assessment, thematic data are projected over feature data on the video display such that individual themes or features could be turned off or on or assigned different colors by manipulating the graphics pad. With ground reference data in hand, classification results of the test sites are then examined to compare the pattern of themes with the pattern of ground cover.

In making this comparison, attention was given to the following parameters. The number and distribution of unclassified pixels was noted as this may show the presence of new ground features or it may indicate the need to expand a signature file. The interface between cover types was also examined, particularly where distinct differences in cover types occurred. Such interfaces would include those between land and water, agriculture and forest and forest wetland. If the pattern of the classified image differed significantly from the pattern of the ground reference data then signature definition of the desired cover types likely had to be redefined. Attention was also given to the number and pattern of pixels that were misclassified. Whether misclassified pixels appeared isolated or in small contiguous blocks was important to note as this gave some indication as to the strength of the filter needed to rectify the "salt and pepper" effect.

When preliminary assessments were completed and the decision was made to conduct further analysis, the first step in post classification work involved generation of check training areas. Check training areas were generated under program IT and contained only those pixels which were known to belong to the same cover type. Ground reference data was used to identify and locate each check training area. Pixels within the check training area were then assigned the appropriate theme value by using the fill mode of the manual theme generation program 'MT'. The result was a new theme file containing only areas of pure theme for each check training area. The theme compare program 'TC' was used to compare check training areas with classification results and a contingency table or confusion matrix was generated.

The next step in the post classification analysis was to apply a custerer or minimum area filter to the classified results using program 'CU'. The filter reduces the "salt and pepper" effect of thematic maps by allowing replacement of small areas (i.e. individual pixels) with thematic information from larger surrounding areas.

The first stage of filtering the map file generation process in which each pixel is assigned a value equal to the size of the contiguous area to which it belongs. The process defines the size of area up to a maximum of 127 contiguous pixels and identifies all those pixels that could not be connected to a defined area. Those pixels that are not connected to a continguous block are flagged as replaceable.

The second stage of filtering is the replacement process where pixels flagged as replaceable may be assigned to a larger neighbouring class. The replacement process can "eat-in" up to a maximum depth of seven pixels; however, the operator cannot choose to exceed the eat-in depth returned as the default from the map generation process. A seven pixel eat-in depth means that the filter will penetrate a contiguous block up to a maximum depth of seven pixels in search of pixels to be replaced. If the default eat-in depth is insufficient to completely replace all replaceable pixels then a second or subsequent passes may be required. The filtering parameters assigned to the classified image for this project were as follows:

STEP ONE: Map File Generation

1. Diagonally connected pixels were considered to be in the same area.
2. Smallest undefined area was 9 pixels.

STEP TWO: Replace Minimum Areas

1. Maximum eat-in depth was 6 pixels.
2. Different minimum areas assigned to each theme as follows:

Theme Number	Description	Minimum Area (Pixels)
1	Agriculture	6
2	Woodland	2
3	Water	1
4	Upland Meadow	2
5	Lowland Meadow	9
6	Unproductive	3
7	Wetland	5

3. Unclassified pixels were treated as a theme and assigned a minimum area of 9.

After the filtered image was produced, the results were compared with the check training areas and another confusion matrix for the filtered results was generated. Area measurements of each theme within every township were calculated for the entire study area using program 'CT'.

The final task in the post classification process was to produce a map of the thematic classification. Normally this is done using program "OA" which produces map files that can be transferred to tape for plotting; however, some difficulties were experienced with the OA software. Therefore, classified results were simply transferred to magnetic tape in the CCT format using the Tape Output or "TO" program and properly formatted for plotting using the Canadian Image Analysis System (CIAS) located in Ottawa. Township lines were hand drawn onto the plots and each map was covered with a clear, high-gloss coating to protect them from smudging and fading.

3. RESULTS AND DISCUSSION

3.1 Preprocessing

Acquisition of uncorrected CCT's from Prince Albert Satellite Station (PASS) and subsequent geometric corrections applied in-house using the ARIES - II software was an efficient means for obtaining geometrically corrected satellite data provided that computer time is available. The resampler task (RS) is extremely CPU-intensive and requires complete access to the video display monitor during batch processing. No other tasks may attach to the video display subsystem while the RS task is active. On average, 3.5 hours per band were required to resample 59 m x 79 m pixels to 50 m x 50 m pixels on an original image size of 1500 lines by 2100 pixels. Including the 6.0 hours per scene required to select GCP's, the total computer time needed to correct all three landsat scenes was approximately 60.0 hours.

The accuracy of geometric corrections depends on the care taken in selecting ground control points. Table 2 shows the mean standard error in the pixel and line direction across each landsat scene. The magnitude of the error is subpixel and can be seen on the image by a slight shift of less than one pixel in either direction across the entire study area. In otherwords, when the geometrically corrected image was overlaid onto a topographic map, the fit was within one pixel.

Table 2. Standard error of pixel and line estimate for three images corrected using 6 GCP's and a first order transformation.

Image Date	Error of Pixel	Error of Line
16/06/74	0.01	0.24
09/09/75	0.48	0.13
19/05/81	0.03	0.00

The amount of computer time required to complete image-to-image registration of 1975 and 1981 scenes was on average 3.9 hours per band.

The additional processing time was attributed to the greater number of lines and pixels associated with the resampled image. Including the 6.0 hours for selecting GCP's total computer time needed for this operation was approximately 21.6 hours.

Subpixel accuracy was also obtained for image-to-image registration. The mean standard error of the pixel was 0.34 pixels and the mean standard error of the line was 0.57. This very slight misregistration could be seen as "fuzzy" boundaries, particularly around shorelines. It was this fuzzy boundary that was most often left unclassified. The classification of remaining land cover types did not appear to be affected.

3.2 Accuracy Assessment of Classification

The ability to correctly classify and accurately locate ground features of interest is a fundamental concern to Landsat users. An assessment of mapping accuracy was made by comparing area measurements of cover types using both air photo interpretation and computer classification results. In addition, a confusion matrix was generated to compare known ground cover types with computer classified results.

Paired comparisons as described by Huntsburger and Billingsley (1974) were made by cover type for three test sites to test the null hypothesis that there is no difference in the area of each cover type as determined by air photo and computer techniques. The first set of area measurements were obtained from air photo interpretation of 1980 photographs. This was then compared with the area measurements for the same area on the classified satellite image. A summary of paired comparisons is shown in Table 3.

Table 3 . Summary of paired comparisons between area measurement techniques for air photo interpretation and maximum likelihood classification.

Cover Type	Sum of Differences	Mean of Differences	Sum of Squares for Differences	Variance of the Differences	Variance of the Mean Differences	Standard Deviation of the Mean Differences	Calculated t - value	$t_{0.05,2}$	Accept (A) or Reject (R) Null Hypothesis
Agriculture	+144	48.0	7256.00	3628.00	1209.33	34.78	1.38	2.92	A
Woodland	+154	51.3	4188.67	2094.33	698.11	26.42	1.94	2.92	A
Water	-34	11.3	704.67	352.34	117.45	10.84	1.04	2.92	A
Upland Meadow	+121	40.3	17044.67	8522.33	2840.78	53.30	0.76	2.92	A
Lowland Meadow	-171	57.0	14198.00	7099.00	2366.33	48.64	1.17	2.92	A
Unproductive Land	-79	26.3	844.67	422.34	140.78	11.87	2.22	2.92	A
Wetland	-203	67.7	4284.67	2142.34	714.11	26.72	2.53	2.92	A

To estimate the mean difference and to test hypotheses about the differences between area measurements, each pair of area measurements were used and treated as a random sample from the population of differences. From probability tables read at the 5 percent probability level and with two degrees of freedom, the table t-value was 2.92. For each cover type the calculated t-value was always less than the table t-value. We therefore, accepted the null hypothesis that there is no difference between air photo area measurements and computer classified area measurements.

Area measurement and percent cover by each cover type for the study area are shown in Table 4. Area measurements by township for each cover type are listed in Appendix II.

Table 4. Percent cover and land area by major cover type for the Rangeland Mapping project area.

Cover Type	Percent	Area (ha)
Woodland	32	212800
Upland Meadow	7	46550
Lowland Meadow	16	106400
Wetland	7	46550
Agriculture	4	26600
Unproductive	2	13300
Water	32	212800

The confusion matrix shown in figure 4 provides further insight into classification accuracy. Of the 9,661 pixels examined 9,176 or 95 percent were correctly classified. Van Genderen and Lock (1977) and Todd and Gehring (1980) point out that from this matrix we can estimate not only the percent of all land that was correctly classified but also the percentage of land correctly classified for each cover type.

The matrix is read by selecting a cover type from the ground reference data column and moving across the table to the corresponding cover type in the supervised classification row. For example, in the woodland category 1,963 pixels out of a total 2,100 were correctly classified as woodland and the remaining 137 pixels were incorrectly classified as other cover types. These incorrectly classified pixels are known as errors of omission.

Errors of omission were highest in the lowland meadow category and lowest in the water category. Of the 343 pixels identified from ground reference data as lowland meadow, only 210 or 61 percent were correctly classified. Lowland meadow was most often confused with water, unproductive land, wetland and woodland. In the agriculture cover type, where 92 percent were correctly classified, most errors of omission resulted when wetland was incorrectly classified as agriculture. In the wetland category, where 92 percent were correctly classified, confusion with lowland meadow was most common. The woodland category, with 93 percent correctly classified, was confused with water and lowland meadow.

SUPERVISED CLASSIFICATION

GROUND REFERENCE DATA

Classified Results / Check Training	Agri-culture	Wood-land	Water	Upland Meadow	Lowland Meadow	Unpro-ductive Land	Wetland	Unclassified Pixels	Number correct	Number wrong	Total	Percent Correct
Agri-culture	1921	6	0	0	16	0	123	0	1921	145	2066	92
Woodland	0	1963	99	2	35	1	0	0	1963	137	2100	93
Water	1	0	3030	0	3	0	2	0	3030	6	3036	99
Upland Meadow	0	0	0	1120	18	0	0	0	1120	18	1138	98
Lowland Meadow	3	23	45	5	210	30	27	0	210	133	343	61
Unproduc-tive Land	0	0	0	0	7	441	0	2	441	9	450	98
Wetland	9	4	3	0	21	0	491	0	491	37	528	92
Number Correct	1921	1963	3030	1120	210	441	491					
Number Incorrect	13	33	147	7	100	31	152					
Total	1934	1996	3177	1127	310	472	643	2			9661	
Percent Correct	99	98	95	99	68	93	76					95

Figure 4. Confusion matrix of manually classified pixels in check training areas versus pixels in results of supervised classification.

By reading the matrix in the vertical direction, errors of commission can be determined. For example, in the water category 3,177 pixels were classified as water; however, only 3,030 pixels or 95 percent were correctly classified according to ground reference data. The errors of commission occurred as a result, 99 woodland and 45 lowland pixels being included into the water category. The greatest error of commission was recorded in the lowland meadow class where 100 of 310 pixels were incorrectly classified. The lowest number of commission errors were recorded in both the agriculture and upland meadow classes.

4. CONCLUSIONS

This project has demonstrated that LANDSAT data can be used to map land cover types for the Agricultural Crown Lands Branch at a level of detail that is sufficient for regional planning. Factors contributing to the success of this application include cover type classification from satellite data that is comparable to Level I cover types of the Crown Lands Branch existing land classification system, accurate cover type identification and generation of useful output products.

The degree to which remote sensing can be incorporated into the Branch's existing programs must be viewed in light of the level of service which they must provide. The Crown Lands Branch has two main functions that include issuance of agriculutural leases and permits of occupation as well as identification of areas to where expansion may occur. Because their primary function relates to lease and permit administration it is important that the Branch's land assessments are accurate and equitable. The use of satellite data for this application is limited because of the restrictions imposed by satellite sensor resolution. When land assessments mean dollars to landowners and ranchers each assessment must be precise and of sufficient detail to meet individual landowner's requirements. Present LANDSAT sensor capabilities cannot fulfill these requirements.

Landsat derived information is better suited to regional applications where small discrepancies in classification will not affect individual landowners. At present there is little demand for regional applications in southern Manitoba; however, in north central regions of the Province where very little detailed information is available there is some potential. Potential applications include assessment of new areas for development, monitoring land cover/land use over time and evaluating the effect of flood or drought conditions.

The effect of flood conditions was not evaluated in this study because good quality satellite data were not available. If the data had been available the technique would have been to identify changes in the area and distribution of cover types between normal and wet conditions.

5. RECOMMENDATIONS

On the basis of this study the following recommendations should be considered:

1) That the Crown Lands Branch conduct a mapping project with satellite data in the present study area when wet conditions during spring and summer prevail.

2) That the Manitoba Remote Sensing Centre continue to monitor the development of remote sensing technology and inform the Crown Lands Branch of development that will permit more detailed studies and other potential applications.

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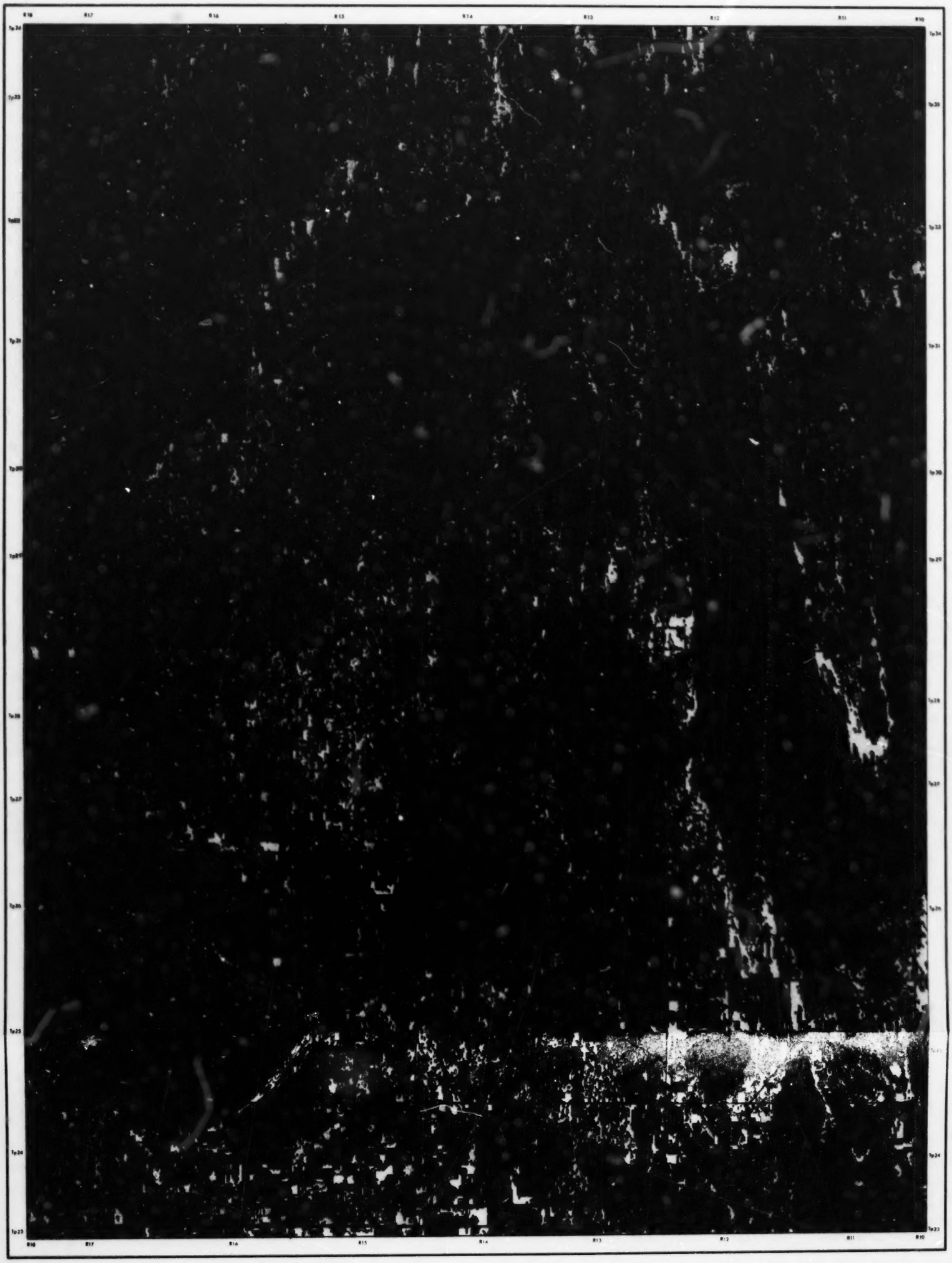
APPENDIX I

Thematic Map for the Rangeland Mapping Project



AGRICULTURE
WOODLAND
WATER
UPLAND MEADOW

WINNIPEGOSIS 62-O/NW

SCALE 1: 250 000

STE ROSE DU LAC 620

SCALE 1: 250 000

LOWLAND MEADOW
UNPRODUCTIVE
WETLAND

APPENDIX II

Land Cover Area Measurements by Township

For Copies of this Information Contact:

Manitoba Remote Sensing Centre
1007 Century Street
Winnipeg, Manitoba R3H 0W4

or

Agricultural Crown Lands Branch
600 - 1495 St. James Street
Winnipeg, Manitoba R3H 0W9

POOR

QUALITY

ORIGINAL